Lithium Electrode Sub-Assemblies (LESAs) Incorporating Nanostructured Lithium-Ion Conducting Composites

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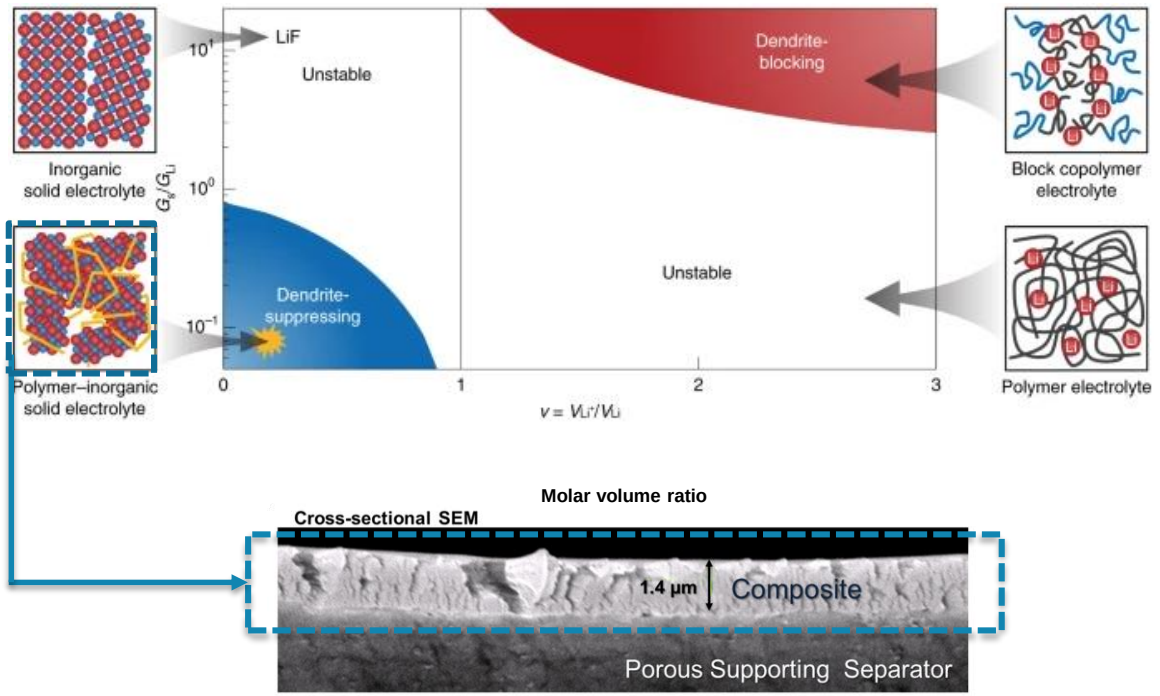
Project Vision

Leverage novel polymer scaffolds to nanostructured high-conductivity inorganic/organic composites that enable high-rate, high-capacity cycling of high energy density Li metal batteries, demonstrated using 24M's unique high areal capacity semi-solid electrode platform.

Total project cost:	$3.3M
Current Q / Total Project Qs	Q16 / Q17

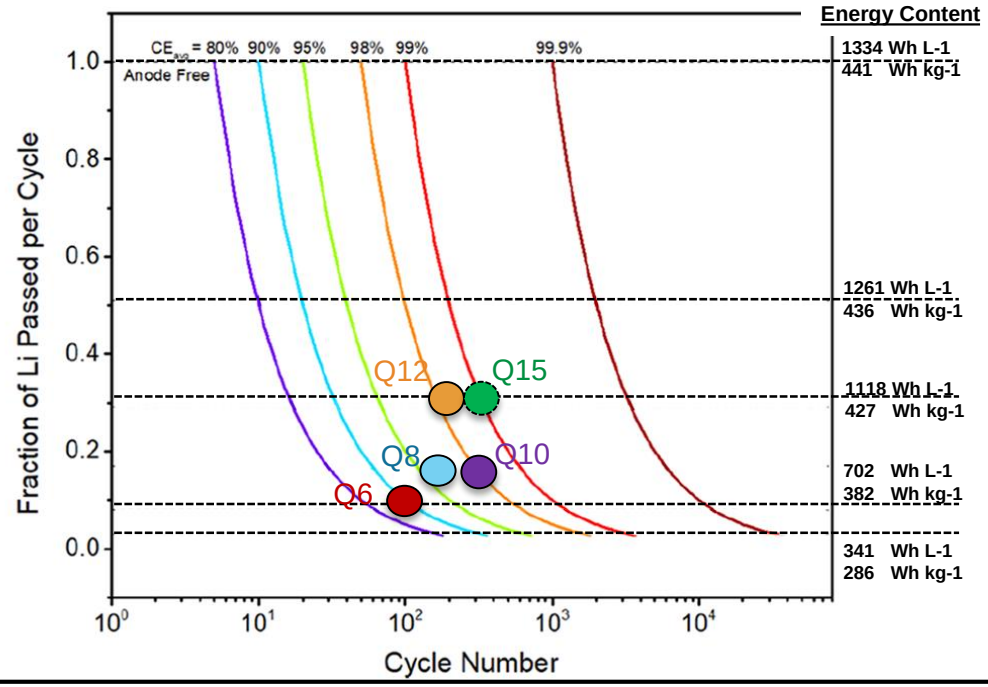
The Concept

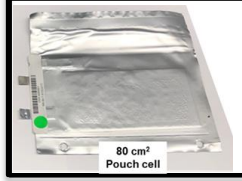
- Composites operating in newly-identified region of stability have been successfully synthesized, applied to separators, and interfaced with lithium metal.



Lithium Electrode Sub-Assembly (LESA)

- Intelligent cell design pairing lithium metal with thick SemiSolid cathodes promises exceptional energy density.





Measured specific energy: 427 Wh/kg

Program target: 400 Wh/kg, state-of-the-art: 350 Wh/kg*

*https://www.energy.gov/eere/articles/battery500-progress-update

Viswanathan and **Helms**, et al. "Universal chemomechanical design rules for solid-ion conductors to prevent dendrite formation in lithium metal batteries." *Nature Materials* **19**, 758 (2020).

Chiang and **Viswanathan**, et al. "Design principles for self-forming interfaces enabling stable lithium-metal anodes." *PNAS* **117**, 27195 (2020).

The Team

Team member	Location	Core Competencies
24M Technologies	Cambridge, MA	Battery Development and Manufacturing 
Carnegie Mellon University	Pittsburgh, PA	Theory, Modeling, and Predictive Analysis 
Lawrence Berkeley National Lab	Berkeley, CA	Composite Development and Characterization 
Sepion Technologies	Emeryville, CA	Composite Development & Processing 

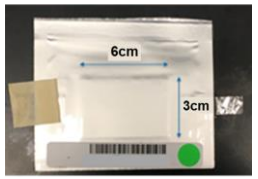
Project Objectives

Year One: Develop LESA chemistry / processing and integrate into battery cell.

Year Two: Scaleup to pouch cells w/ 24M's SemiSolid technology and improve LESA to reach 200 cycles.

Year Three: Scale-up to 80 cm^2 pouch with a cell design > 400 Wh/kg and > 1000 Wh/L.

Plus-Up: Optimize for eVTOL and EV end-use applications and reach 500 cycles.



Y1	Y2	Y3	Plus-Up
Li per cycle ≥ 1 mAh/cm^2	Li per cycle ≥ 2 mAh/cm^2	Li per cycle > 6 mAh/cm^2	Li per cycle > 6 mAh/cm^2
100 cycles @ ≥ 1mA/cm^2	200 cycles @ ≥ 2mA/cm^2	>300 cycles* @ ≥ 3 mA/cm^2 > 400 Wh/kg, > 1000 Wh/L *projection	500 cycles @ ≥ 3mA/cm^2 > 400 Wh/kg, > 1000 Wh/L Peak Power > 1 kW/kg

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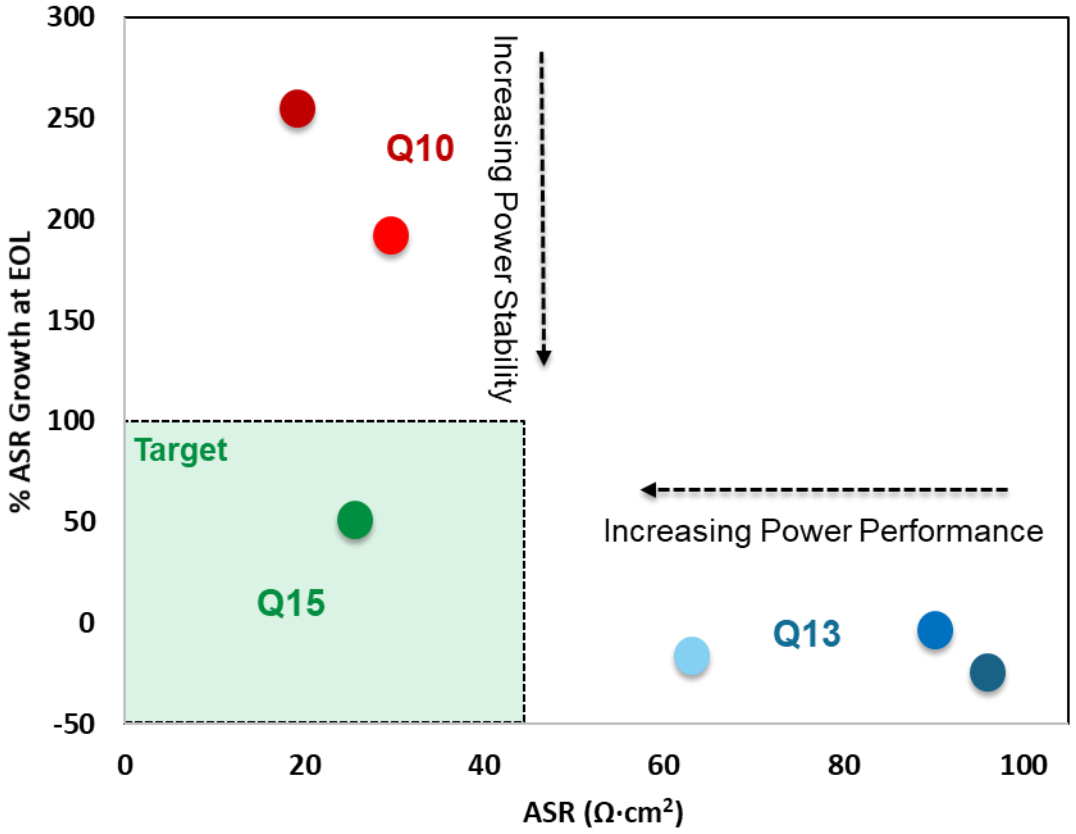
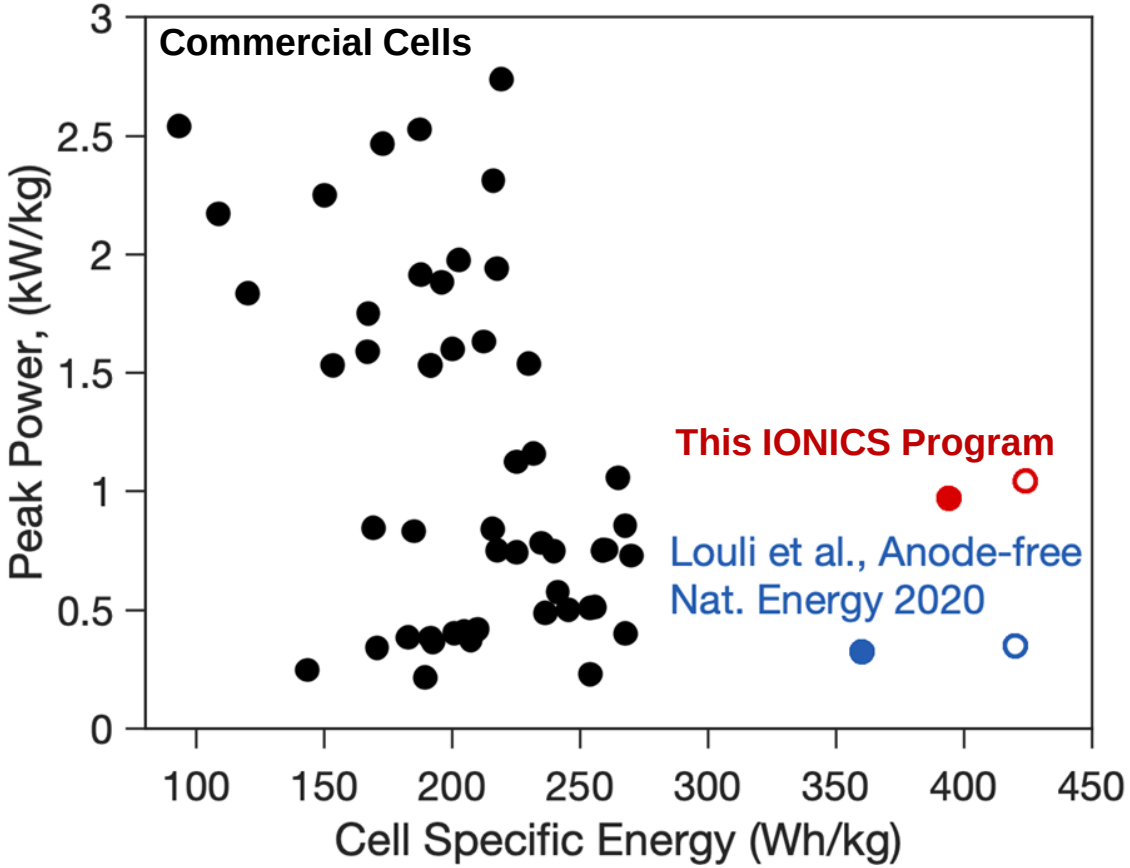
CHANGING WHAT'S POSSIBLE

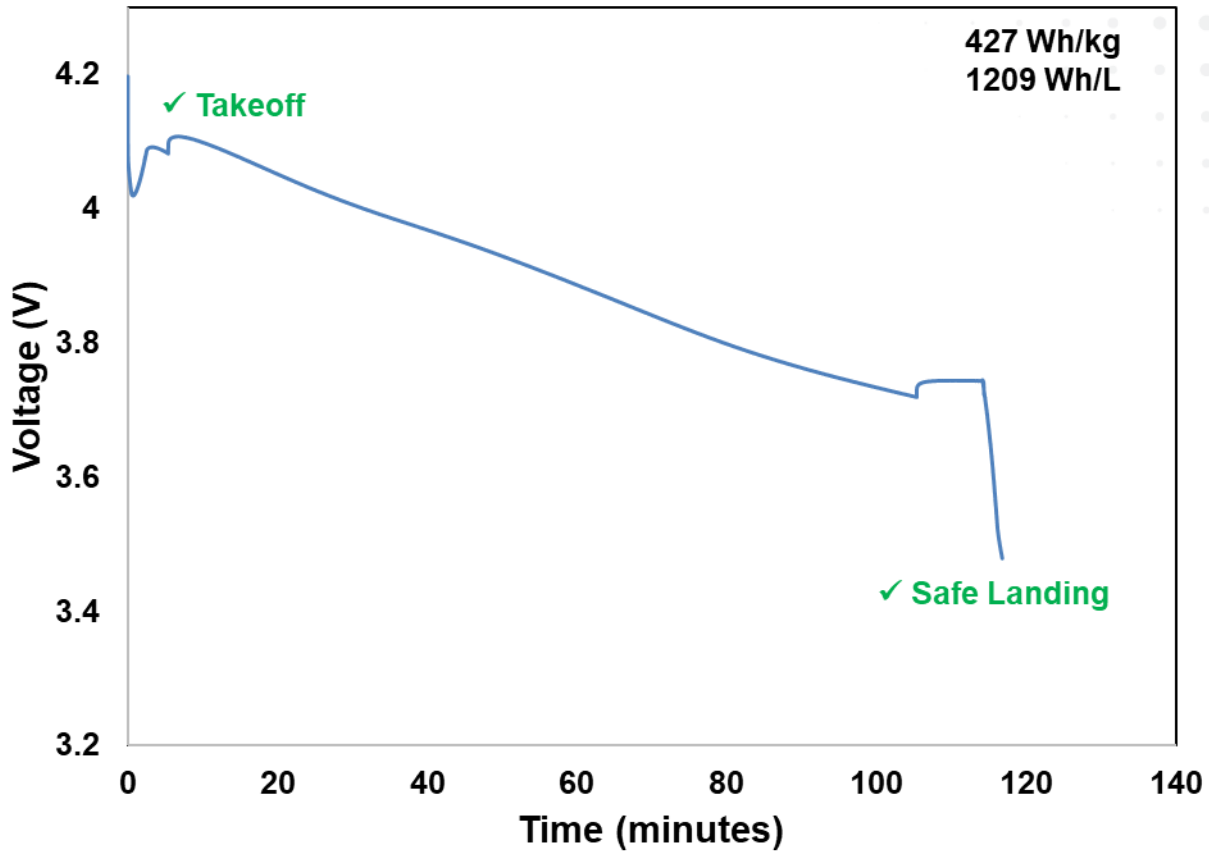
Cell Optimization for End-Use Applications



- Cell design optimized for power performance in eVTOL application for cycle life in EV application

eVTOL Testing – Best in Class





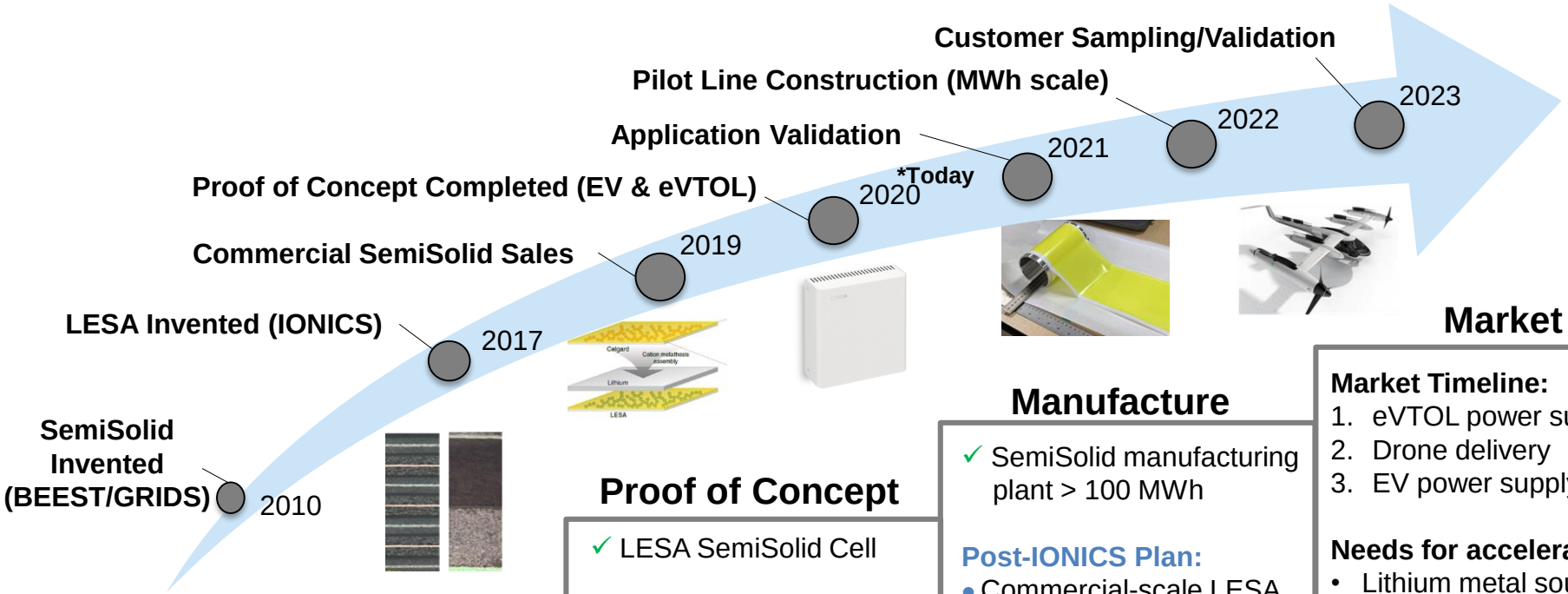
Fredericks, W.L., Sripad, S., Bower, G.C. and **Viswanathan, V.,** 2018. ACS Energy Letters, 3(12), pp.2989-2994.

- Energy density achieved with SemiSolid Li-metal is an enabling technology for eVTOL applications

Challenges, Risks and Potential Technical Partnerships

- **Challenges and Risks**
  - High quality and consistent Li-metal supply
  - Maintaining low ASR to reduce power fade high-power eVTOL applications
  - Pack design incorporating cell compression for Li-metal performance
  - Electric aircraft market development
- **Mitigation**
  - Partnerships with pack manufacturers
  - eVTOL commercial partners, parallel development of EV-capable cells
- **Additional Partnership Opportunities**
  - Lithium metal supplier
- **Capabilities**
  - SemiSolid manufacturing platform is material agnostic and we are constantly seeking new and improved active materials to incorporate into our design
- **COVID Best Practices**
  - Staggered shifts to reduce employee concentration on site and remote internal and external meetings
  - Automated and robotic experimentation (https://www.wsj.com/articles/electric-car-batteries-get-a-boost-from-artificial-intelligence-11604422792)

Technology-to-Market



Objectives

Anticipated Product:
SemiSolid cell with LESA

Approach: Component supplier to battery OEMs

Proof of Concept

- ✓ LESA SemiSolid Cell
- ✓ Pilot R2R LESA membrane
- ✓ eVTOL test demo
- ✓ SemiSolid platform validated w/ market sales

Manufacture

- ✓ SemiSolid manufacturing plant > 100 MWh

Post-IONICS Plan:

- Commercial-scale LESA anode manufacture
- Integrate LESA with SemiSolid manufacture platform
- Pilot production line

Market

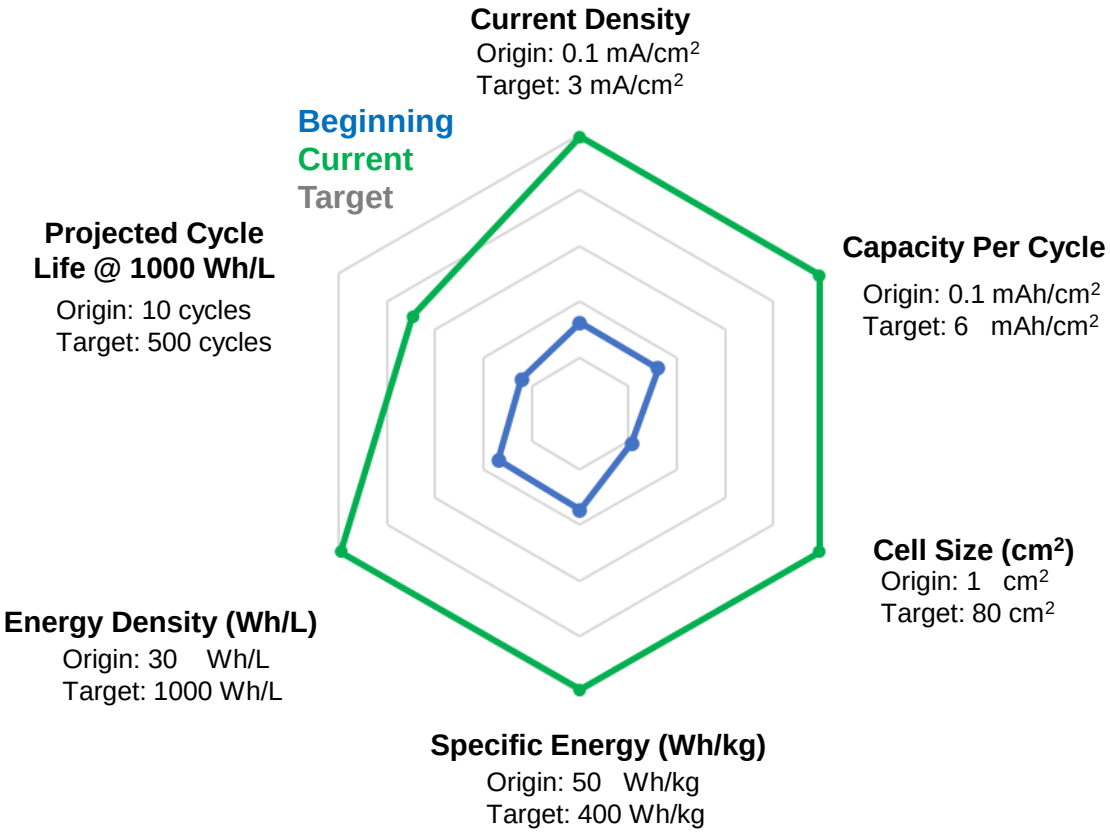
Market Timeline:

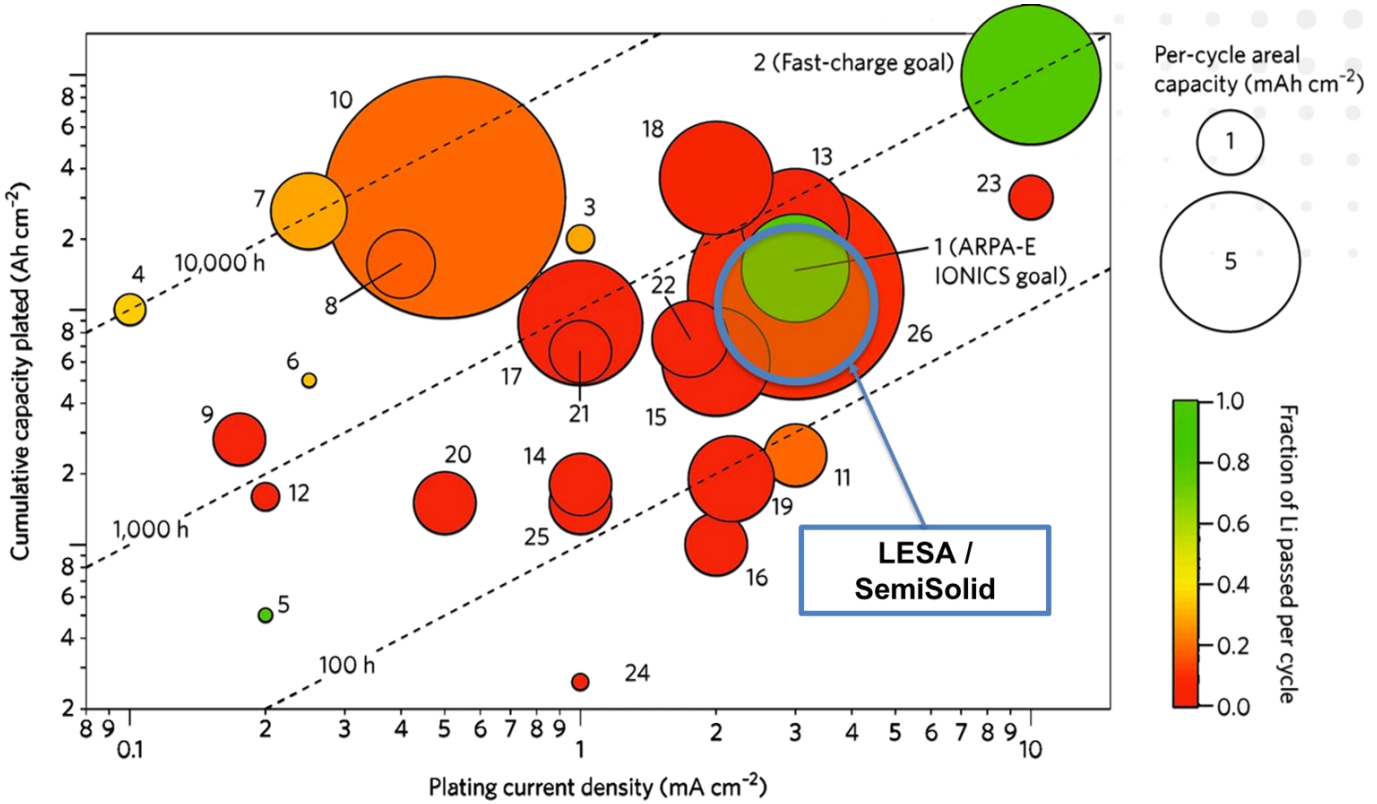
1. eVTOL power supply
2. Drone delivery
3. EV power supply

Needs for acceleration:

- Lithium metal sourcing
- eVTOL and EV partnerships
- Pack manufacturer partnerships

Summary Slide





Final Deliverable: ·5x > 80 cm² pouch cells which satisfy above target metrics under constant current test conditions.

Plus-Up Deliverable: ·5x > 80 cm² pouch cells which satisfy above target metrics under eVTOL test conditions.

·3x multi-layer pouch cells > 2 Ah.